Phase behavior of colloidal suspensions of rods and spheres

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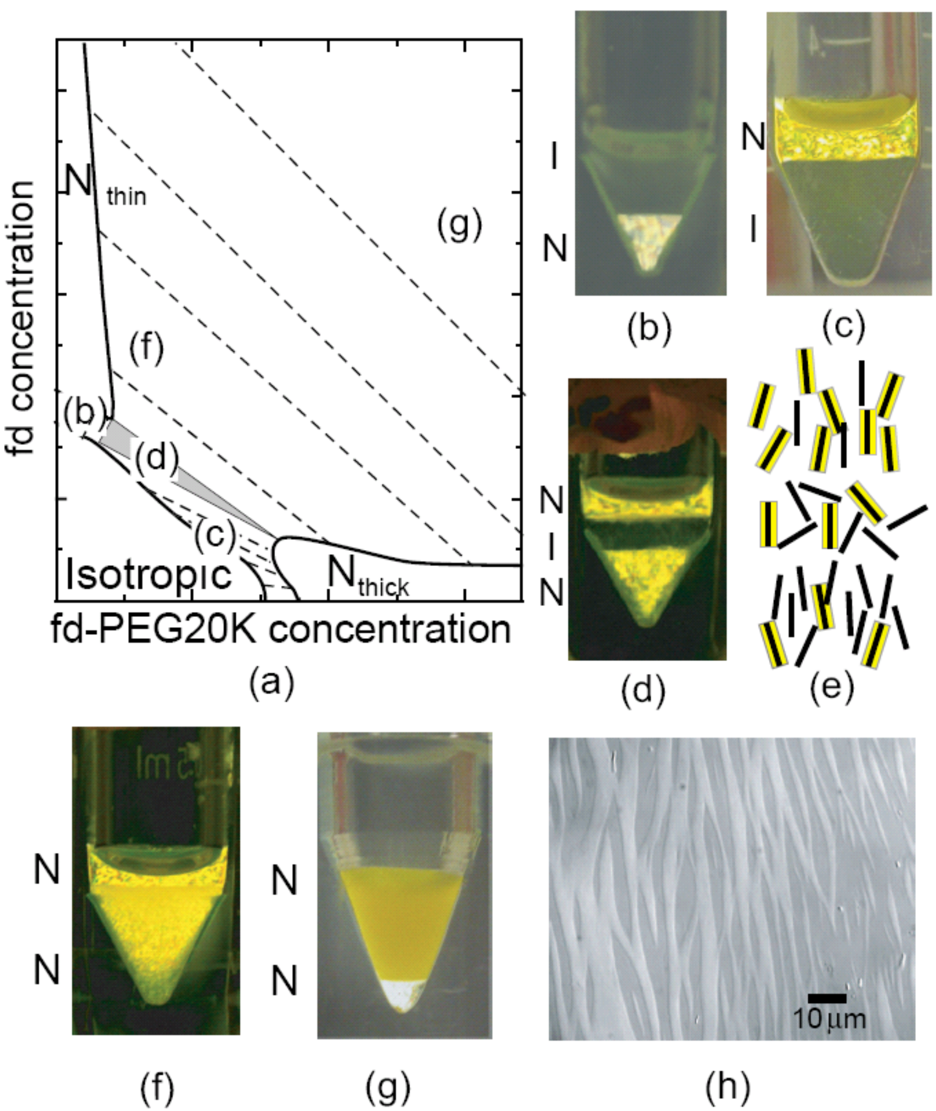

Filamentous colloids are abundant in biology and industry. We study the liquid crystalline phase behavior of mixtures of filaments composed of thin, fd virus, and thick, fd virus sterically stabilized with covalently bound polymer poly(ethylene glycol) (fd-PEG). In solution, binary mixtures of fd and fd-PEG exhibit two phase isotropic-nematic (I-N) and nematic-nematic (N-N) co-existence, as well as three phase isotropic-nematic-nematic (I-N-N) co-existence. Our measurements resolved a theoretical controversy concerning the topology of the phase diagram and demonstrated that the phase behavior is dominated by entropy, leading to a deepened understanding of how to engineer colloids that spontaneously organize into useful structures. Potential applications are in the field of biosensors and nanotechnology.

http://lanl.arxiv.org/abs/cond-mat/0406175

Colloids are particles of size ranging from 5 to 1000 nm suspended in a solvent and are small enough such that thermal energy dominates other interactions that act on them such as gravity and interparticle forces. In our current NSF grant 0088008 we studied rodlike colloids, important biological examples being filamentous proteins such as actin and microtubules, DNA, and filamentous viruses. Important industrial applications also exist, for example the rodlike clay colloid bentonite is used as a oil-well drilling lubricant because it has tremendous shear thinning properties as a consequence of its shape. Typically, spherical and rodlike colloids are present together, or the rods are polydisperse, hence our motivation to study the phase behavior of mixtures of rods and spheres and mixtures of rods of different lengths and diameters.

As an experimental system of rodlike colloids we utilized a family of viruses related to filamentous phage fd. A number of features render filamentous phage a particularly attractive experimental system for fundamental studies of liquid crystals and self-assembling systems. First, genetic engineering allows the systematic modification of the most important physical properties of the virus such as its length and charge per unit length. Some mutants are present naturally (M13, fd) while others were created in our laboratory for this project. A second important feature is the monodispersity of the viruses. No commercially available rodlike colloid or polymer approaches viruses in this regard. Even when the effects of polydispersity are studied, it can be done systematically by first creating bidisperse samples and subsequently increasing the polydispersity in a controlled manner. Third is the ability to modify the virus chemically after it has been expressed. We sterically stabilized the virus by grafting poly(ethylene) glycol (PEG) to the virus. We also have fluorescently labeled the virus allowing the visualization of the dynamics of single viruses inside equilibrated samples.

Theoretical modeling of the self-assembly and ordering of rodlike colloids requires making approximations. Our experiments, described here, have been able to establish the limits of validity of current theories and to pick which one of several theories correctly models experiment. With each such success we advance our ability to engineer self-assembled structures of increasing complex and sophisticated properties. Potential applications range from advanced composite materials, such as carbon nanotube fibers, to biosensors that can detect antigens.

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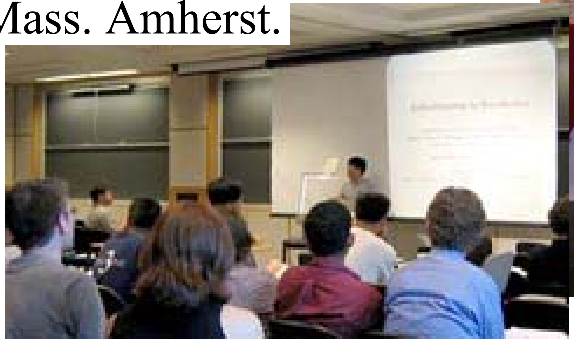
Public Outreach: New England Complex Fluids Workshop

In 1999, Dave Weitz (Harvard) and Fraden organized quarterly workshops for complex fluids researchers. The goal is to encourage collaboration among researchers from industry and academe in the New England area studying Soft Condensed Matter. An additional objective of the workshop is to help the career development of students and post-docs by introducing them to the local academic and industrial research community. The location of the workshop rotates among the member institutions and with attendance ranging from 40 to 100 people. Meetings have been held at Boston University, Brandeis University, Brown University, Clark University, Harvard University, Massachusetts Institute of Technology, the Universities of Massachusetts at Amherst and Boston, and Yale University. At far right is the 18th workshop at Brown, and below is the 19th workshop at U. Mass. Amherst.



http://complexfluids.org

This grant supported two Ph.D. students, three undergraduates, and one post-doc. Zvonimir Dogic received his PhD in 2001 and currently is a Junior Fellow of the Rowland Institute, Harvard University. Dr. Dogic is an exceptionally talented researcher who recently adopted American citizenship. NSF's financial support for Dr. Dogic's graduate training and scientific development played an essential role in the recruitment of Dr. Dogic into the American research community. The second graduate student, Kirstin Purdy, started her research in 2000 and will receive her PhD in F2004.

This grant supports the complex fluids efforts of my laboratory. As part of our outreach from this grant and as a way to leverage the collected facilities and intellectual capital of the universities in New England I co-founded the New England Complex Fluids Workshop, a quarterly meeting of researchers in the field of complex fluids. The goals of the meeting are described above and over 400 people have registered and attended some of our workshops. There have been several collaborations that have resulted from these meetings, many instances of shared instrumentation usage, and several graduate students have gone on to do post-docs with professors they met at the workshops.